

Silicon Tracking for fSTAR

RHIC Spin Collaboration Meeting
March 9-10, 2017, BNL

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Outline

- Physics Motivation
- Forward Tracking Requirements
- Silicon-Based Forward Tracker
- Summary

Forward Upgrade for pp/pA Physics

	Year	\sqrt{s} (GeV)	Delivered Luminosity	Scientific Goals	Observable	Required Upgrade
Scheduled RHIC running	2017	p ⁺ p @ 510	400 pb ⁻¹ 12 weeks	Sensitive to Siverts effect non-universality through TMDs and Twist-3 $T_{q,F}(x,x)$ Sensitive to sea quark Siverts or ETQS function Evolution in TMD and Twist-3 formalism Transversity, Collins FF, linearly pol. Gluons, Gluon Siverts in Twist-3 First look at GPD Eg	A_N for γ , W^\pm , Z^0 , DY $A_{UT}^{\sin(\phi_s-2\phi_h)}$ $A_{UT}^{\sin(\phi_s-\phi_h)}$ modulations of h^\pm in jets, $A_{UT}^{\sin(\phi_s)}$ for jets A_{UT} for J/ Ψ in UPC	A_N^{DT} : Postshower to FMS@STAR None None
	2023	p ⁺ p @ 200	300 pb ⁻¹ 8 weeks	subprocess driving the large A_N at high x_F and η evolution of ETQS fct. properties and nature of the diffractive exchange in p+p collisions.	A_N for charged hadrons and flavor enhanced jets A_N for γ A_N for diffractive events	Yes Forward instrum. None None
	2023	p ⁺ Au @ 200	1.8 pb ⁻¹ 8 weeks	What is the nature of the initial state and hadronization in nuclear collisions Nuclear dependence of TMDs and nFF Clear signatures for Saturation	R_{pAu} direct photons and DY $A_{UT}^{\sin(\phi_s-\phi_h)}$ modulations of h^\pm in jets, nuclear FF Dihadrons, γ -jet, h-jet, diffraction	$R_{pAu}(DY)$: Yes Forward instrum. None Yes Forward instrum.
	2023	p ⁺ Al @ 200	12.6 pb ⁻¹ 8 weeks	A-dependence of nPDF, A-dependence of TMDs and nFF A-dependence for Saturation	R_{pAl} direct photons and DY $A_{UT}^{\sin(\phi_s-\phi_h)}$ modulations of h^\pm in jets, nuclear FF Dihadrons, γ -jet, h-jet, diffraction	$R_{pAl}(DY)$: Yes Forward instrum. None Yes Forward instrum.
	202X	p ⁺ p @ 510	1.1 fb ⁻¹ 10 weeks	TMDs at low and high x quantitative comparisons of the validity and the limits of factorization and universality in lepton-proton and proton-proton collisions	A_{UT} for Collins observables, i.e. hadron in jet modulations at $\eta > 1$ and mid-rapidity observables as in 2017 run	Yes Forward instrum. None
Potential future running	202X	$\bar{p}^+\bar{p} @ 510$	1.1 fb ⁻¹ 10 weeks	$\Delta g(x)$ at small x	A_{LL} for jets, di-jets, h ⁰ / γ -jets at $\eta > 1$	Yes Forward instrum.

Table 1-2: Summary of the Cold QCD physics program proposed in the years 2017 and 2023 and if an additional 500 GeV run would become possible.

Forward Upgrade for AA Physics

Physics Measurements		Longitudinal de-correlation $C_n(\Delta\eta)$ $r_n(\eta_a\eta_b)$	$\eta/s(T)$, $\zeta/s(T)$	Mixed flow Harmonics $C_{m,n,m+n}$	Ridge	Event Shape and Jet-studies
Detectors	Acceptance					
Forward Calorimeter (FCS)	$-2.5 > \eta > -4.2$ E_T (photons, hadrons)	One of these detectors necessary		One of these detectors necessary	Good to have	One of these detectors needed
Forward Tracking System (FTS)	$-2.5 > \eta > -4.2$ (charged particles)		Important ✓		Important ✓	

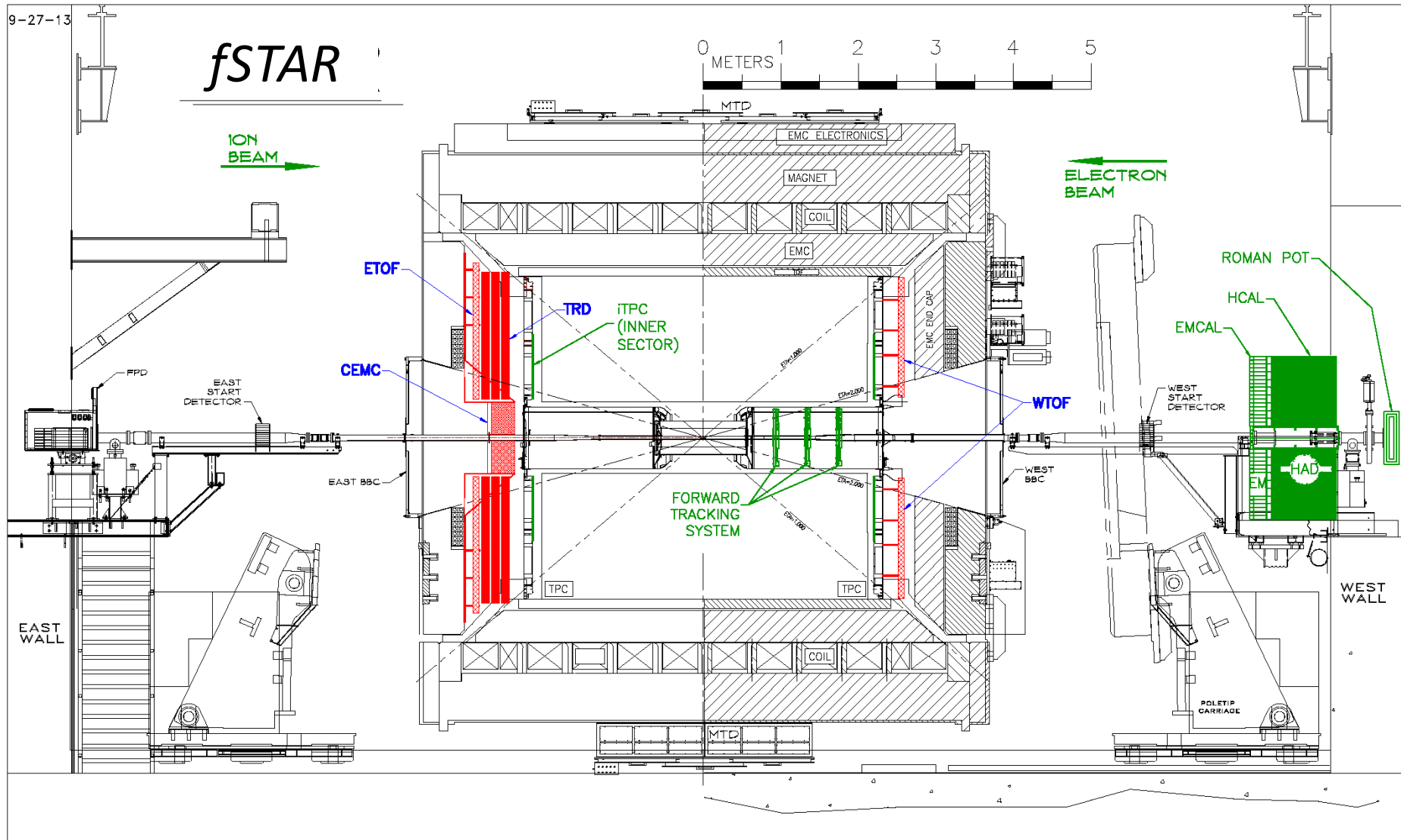
Table 2-1: Physics measurements in A+A collisions with the proposed forward upgrade and with other STAR upgrades that are relevant to those measurements.

Forward Tracking Requirements

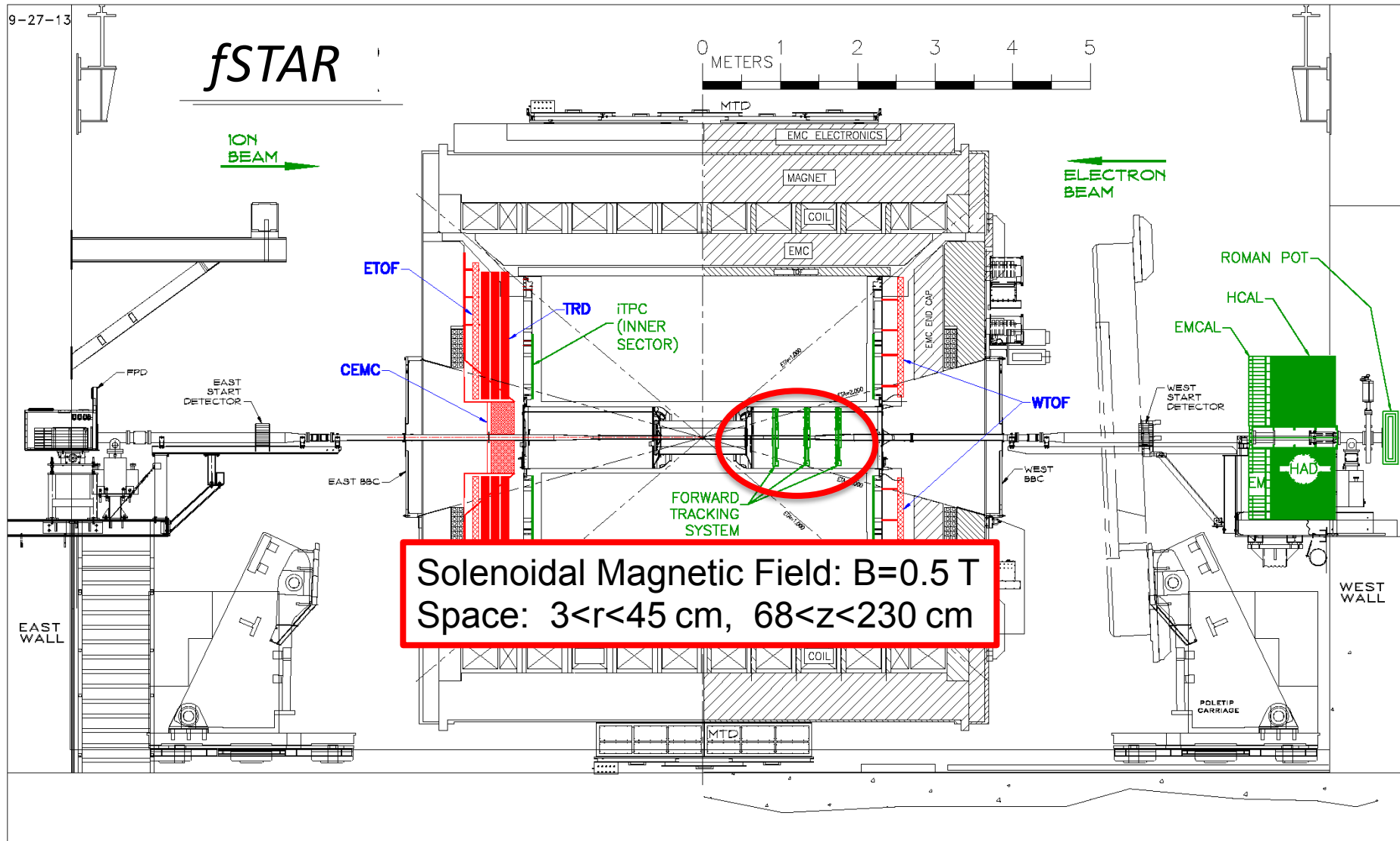
- pp/pA physics – forward
 - charge separation for π^+/π^- , di-hadron, Drell-Yan (q)
→ low mass, good ϕ resolution
 - e/h discrimination for Drell-Yan (p/E)
→ good ϕ resolution
 - e/ γ discrimination for direct photon, Drell-Yan (hit veto)
→ low mass, high efficiency
 - Reconstruction of jets (p)
→ large η coverage, good ϕ resolution
- AA physics – forward
 - Longitudinal fluctuation/even-shape engineering (p)
→ low occupancy, good ϕ resolution, large η coverage
 - Long range correlation (p)
→ low occupancy, good ϕ resolution, large η coverage

Good ϕ resolution
Large η coverage
High efficiency
Low occupancy
Low mass
Low cost

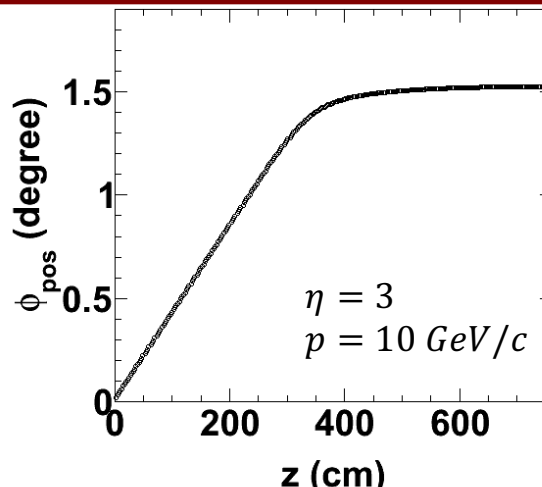
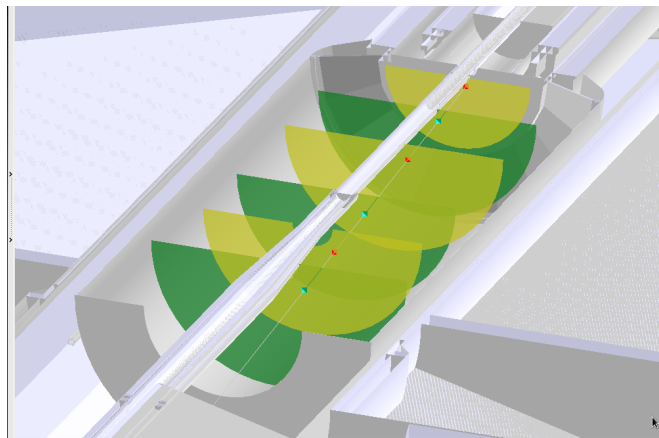
Location & Space Constraints



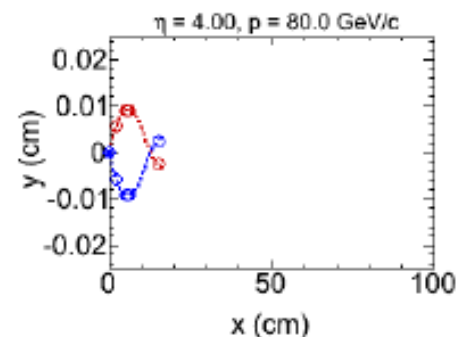
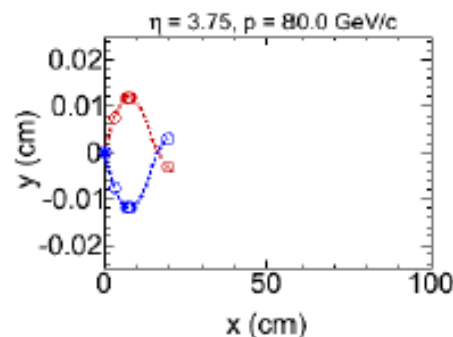
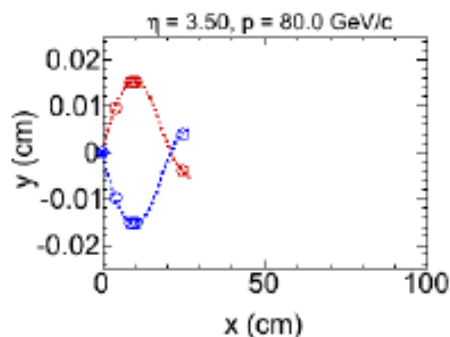
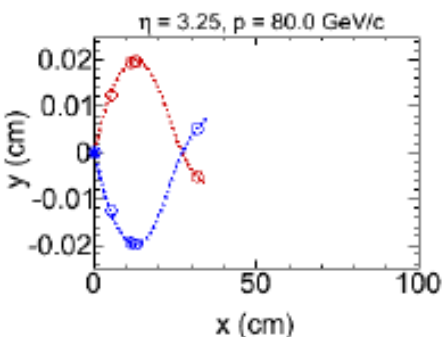
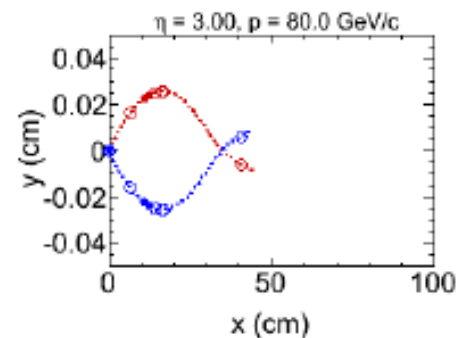
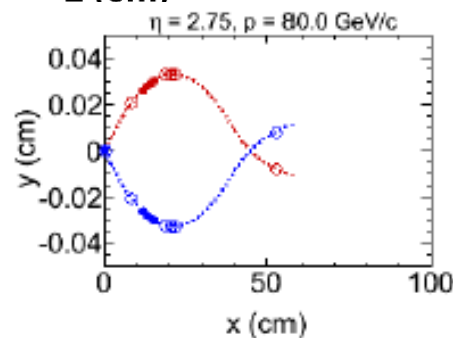
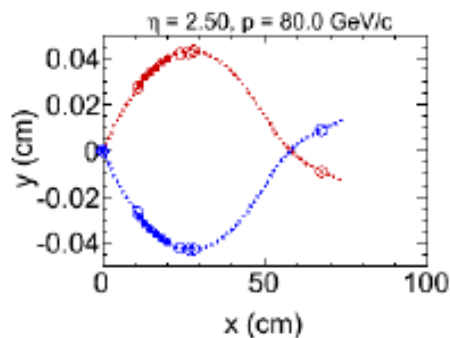
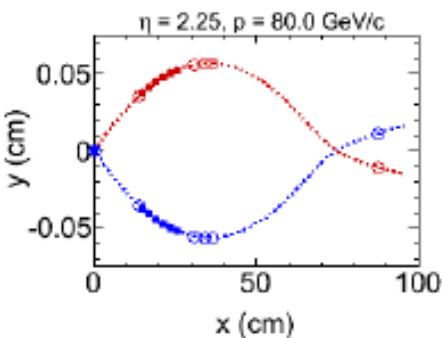
Location & Space Constraints



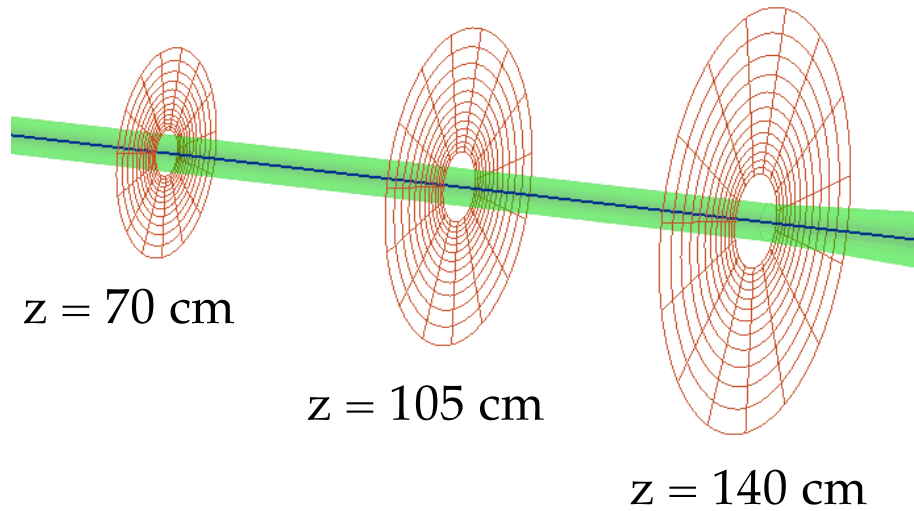
Particle Deflection in Magnetic Field



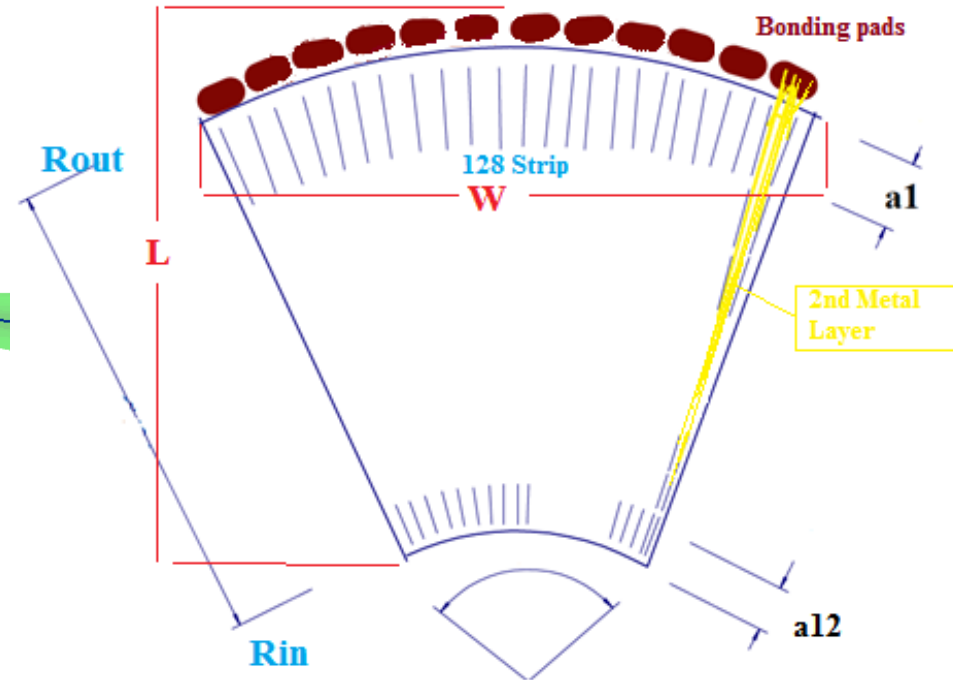
- Particle deflection inside a 0.5 T field along z direction
- Position resolution:
 $R: \sim 1 \text{ cm}$
 $\phi: \sim 20 - 100 \mu\text{m}$



Layout with uniform width in η

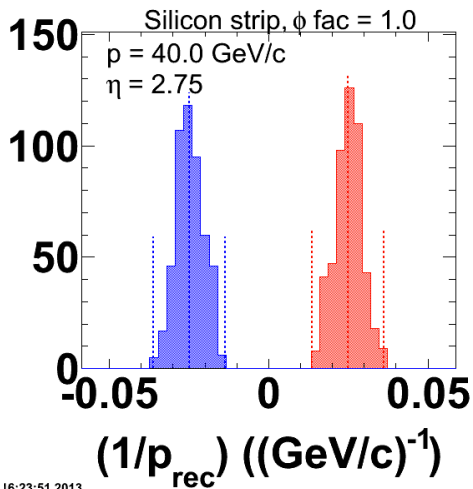


Material budget: $<0.5\% X_0$ per plane

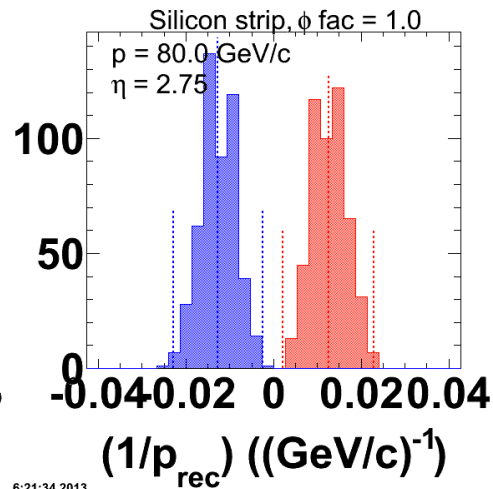


in [mm]	r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8	r_9	r_{10}	r_{11}	r_{12}	r_{13}
plane 1	25.7	29.1	32.9	37.3	42.3	48.0	54.4	61.6	69.9	79.2	89.9	102.0	115.7
ϕ pitch	0.11	0.12	0.15	0.17	0.19	0.21	0.24	0.28	0.31	0.34	0.38	0.43	
plane 2	38.5	43.6	49.4	56.0	63.5	71.9	81.5	92.4	104.8	118.9	134.8	152.9	173.5
ϕ pitch	0.17	0.18	0.22	0.26	0.28	0.32	0.36	0.42	0.46	0.51	0.56	0.64	
plane 3	51.3	58.1	65.9	74.7	84.6	95.9	108.7	123.3	139.8	158.5	179.7	203.9	231.4
ϕ pitch	0.22	0.25	0.29	0.34	0.38	0.43	0.48	0.56	0.61	0.68	0.75	0.85	

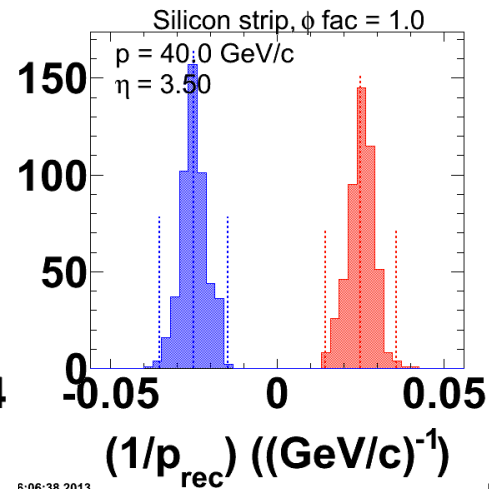
Performance from Simulation



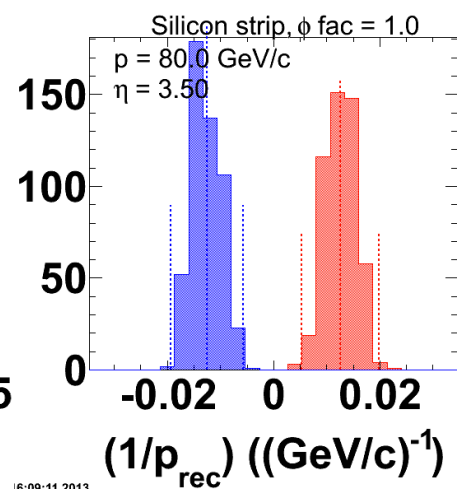
16:23:51 2013



6:21:34 2013

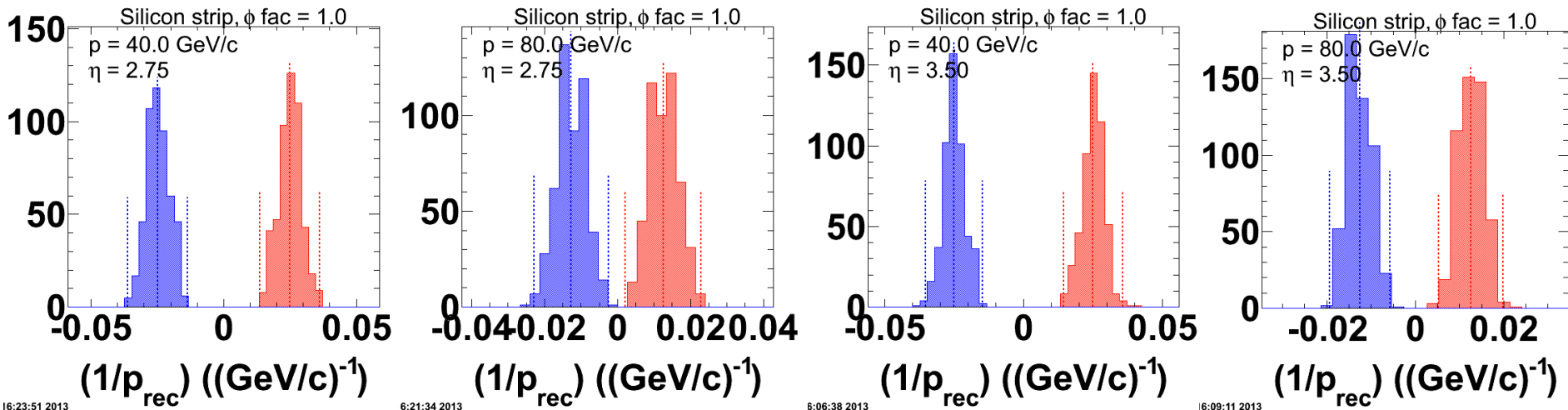


6:06:38 2013



6:09:11 2013

Performance from Simulation

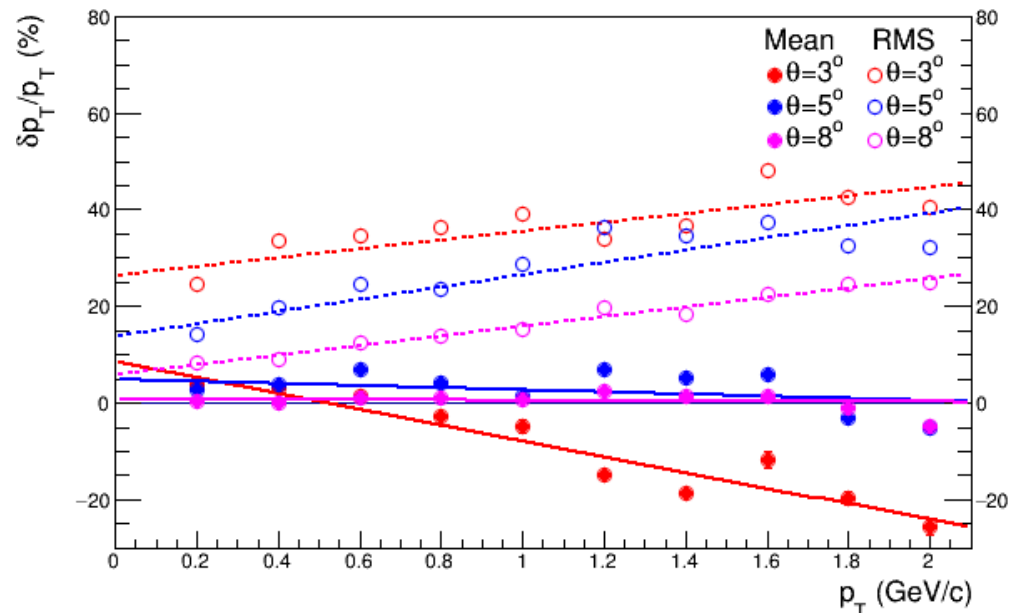
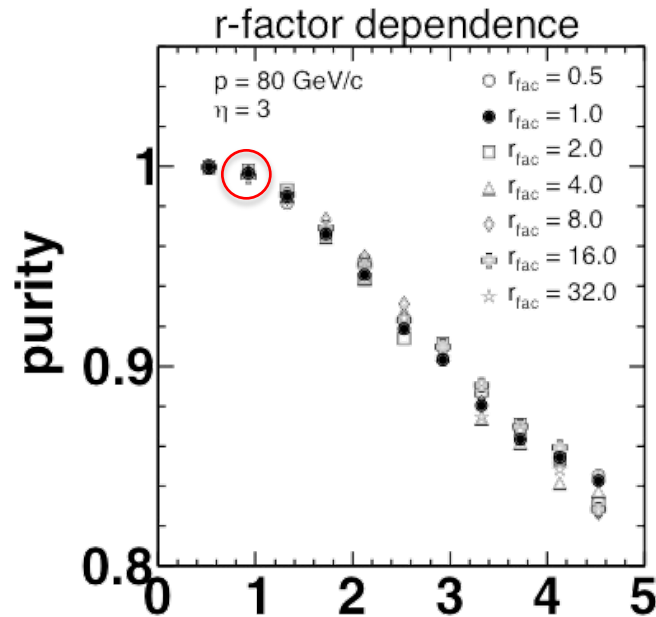


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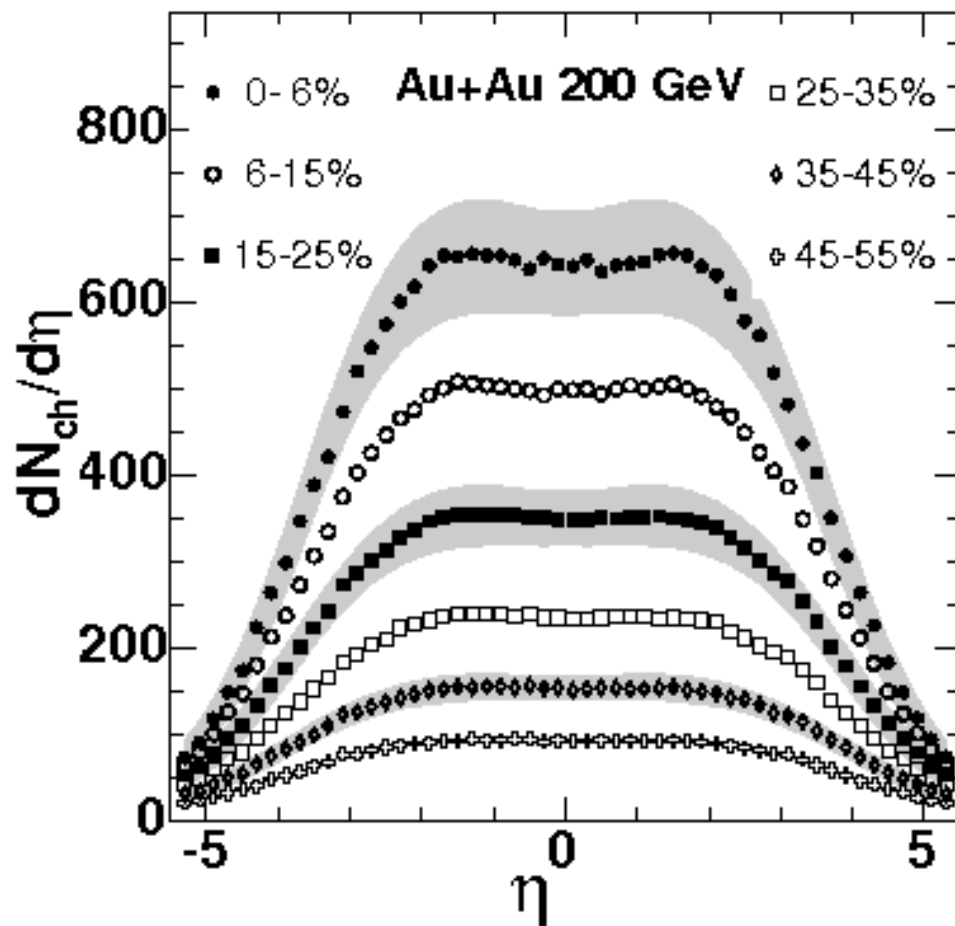
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Occupancy

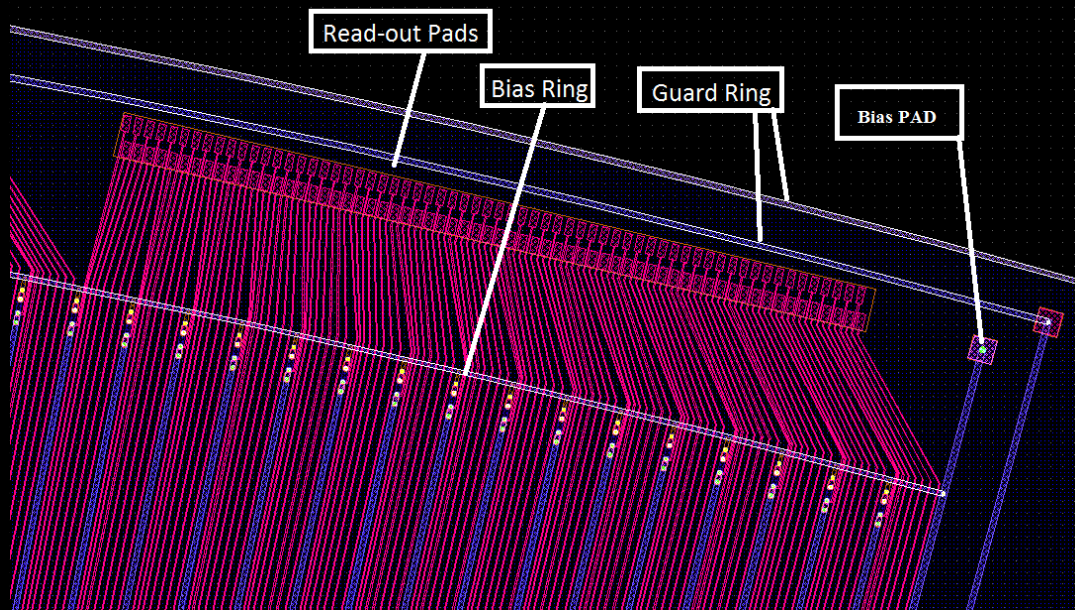
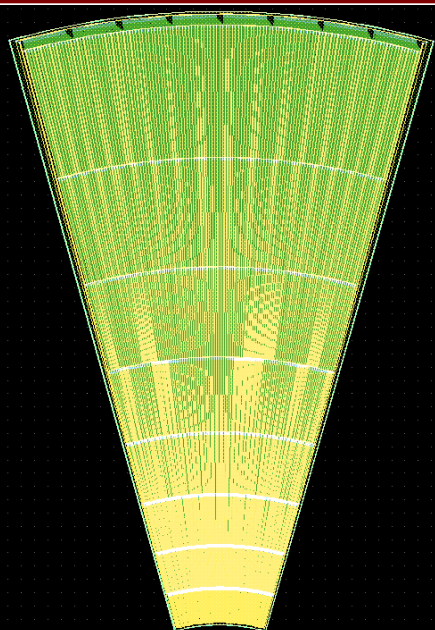


Assume total track=2*primary tracks:

Occupancy \leq 5% (inner R)
10% (outer R)

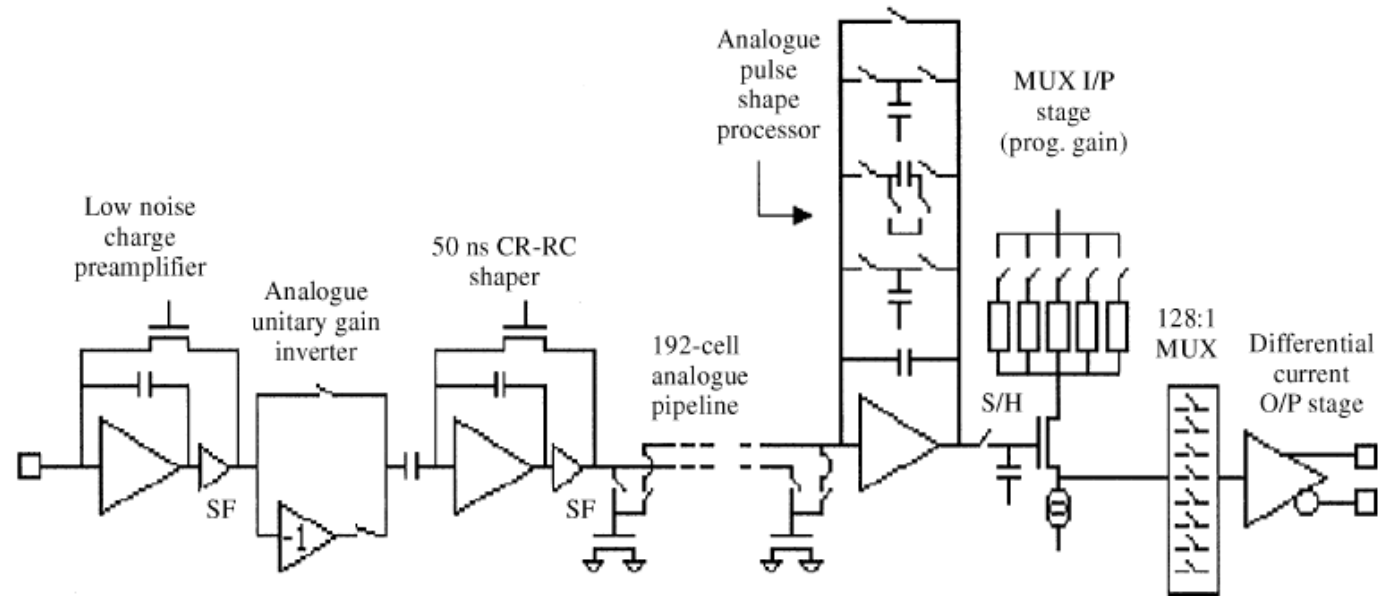
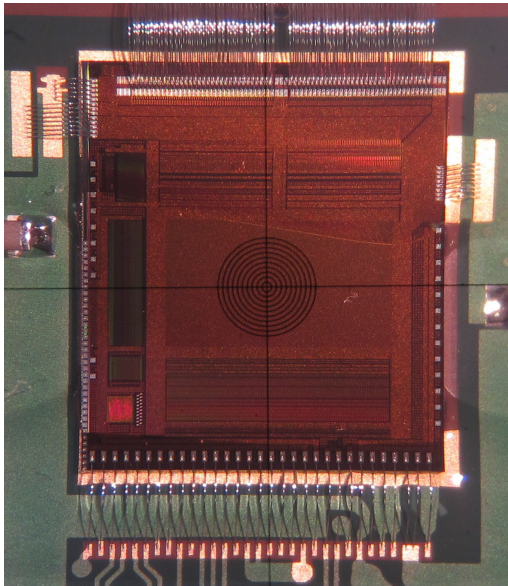
in 0-3% Au+Au collisions at 200 GeV

Silicon Sensors



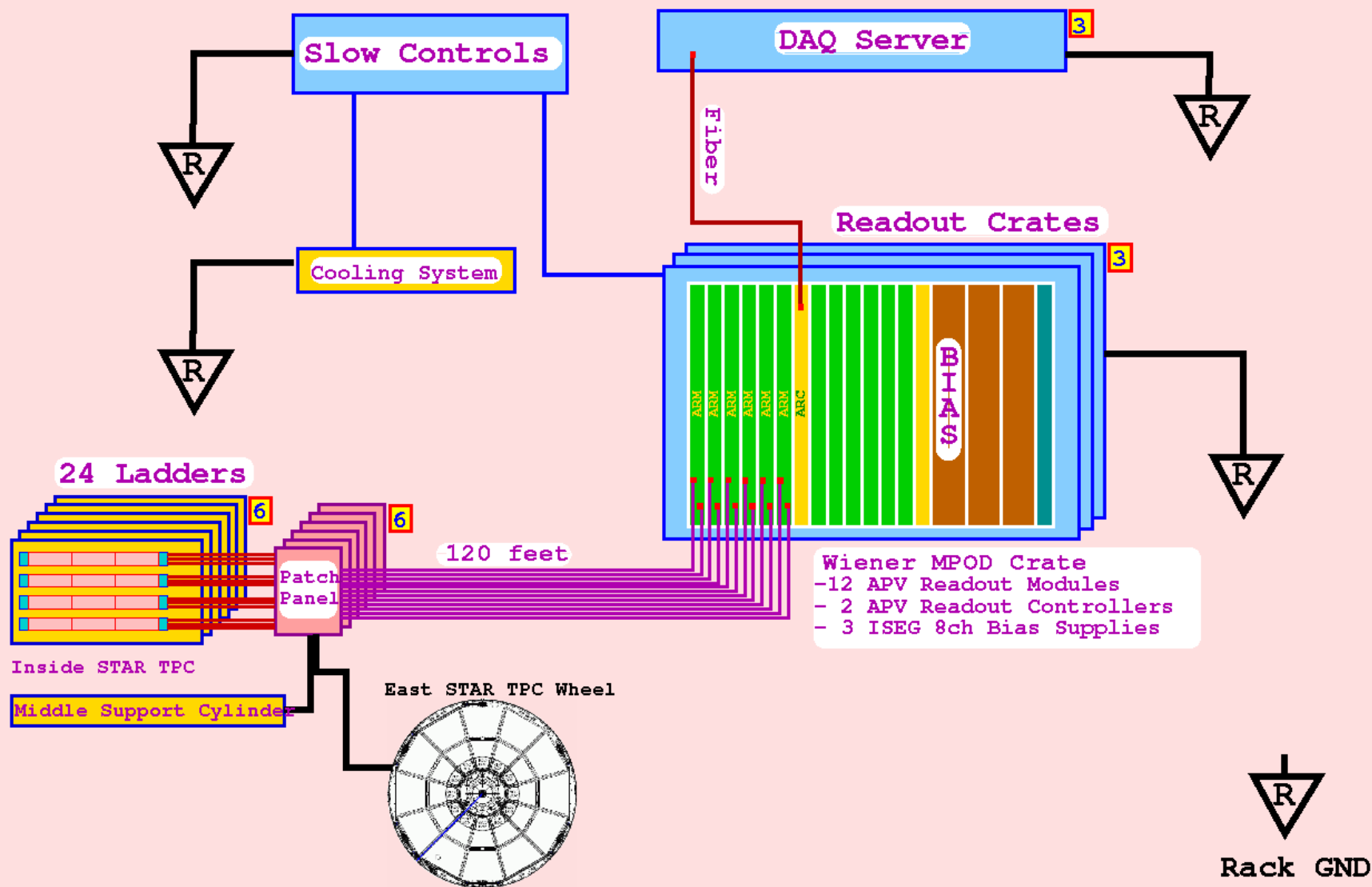
- Single-sided double-metal silicon ministrip sensors
- 8x128 strips per sensor, read out from the outer radius
- R&D needed to validate and optimize sensor design

Front-end Readout ASIC – APV25



- 128 channels per chip, used successfully for STAR IST
- 1200 probe-tested chips in hand
- No R&D needed

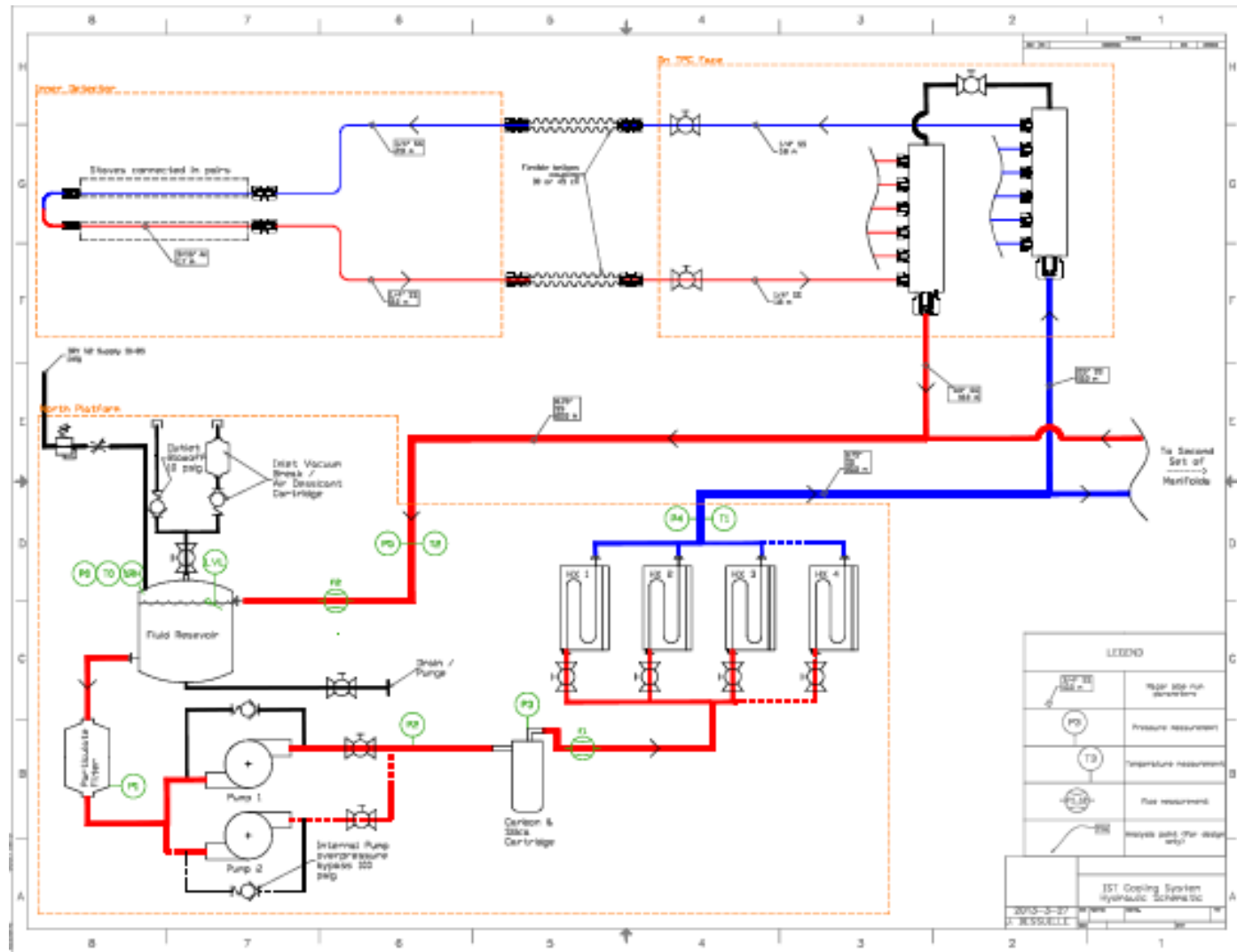
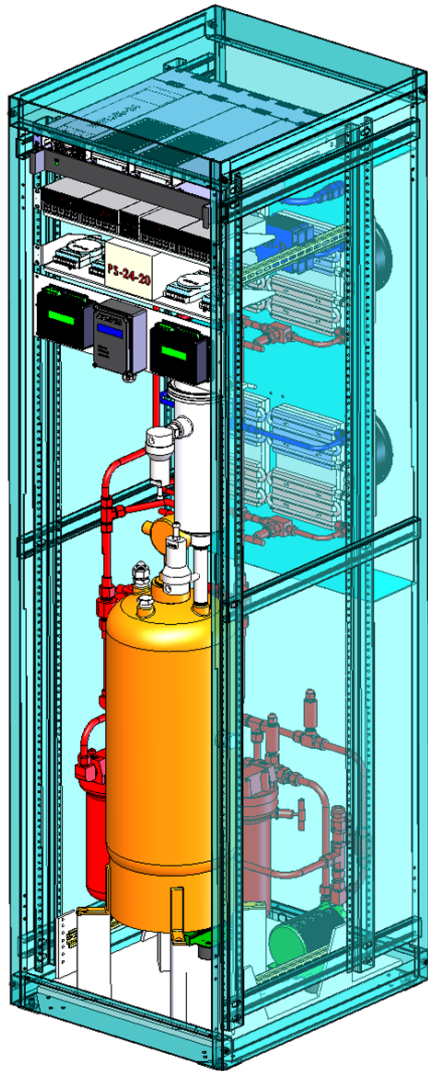
DAQ System



IST DAQ system with firmware modifications can easily handle 5 kHz

Z.Ye, 3/9/2017

Cooling System



Non-ionization radiation: $< 1 \times 10^{13}$ [$1 \text{ MeV neutron/cm}^2$]

Can use IST cooling system with liquid cooling in room temperature

Cost Estimation

Labor and contingency included:

WBS Number	WBS Description FTS (6-disk)	Base Cost	Contingency
y.1.1	Electronics	\$1,100,000	\$330,000 (30%)
y.1.2	Mechanics	\$1,100,000	\$495,000 (45%)
y.1.3	Assembly and Testing	\$560,000	\$196,000 (35%)
y.1.4	Integration	\$450,000	\$225,000 (50%)
Base Cost		\$3,210,000	
Contingency		\$1,246,000	
Total Cost		\$4,456,000	→ \$4,036,000 *

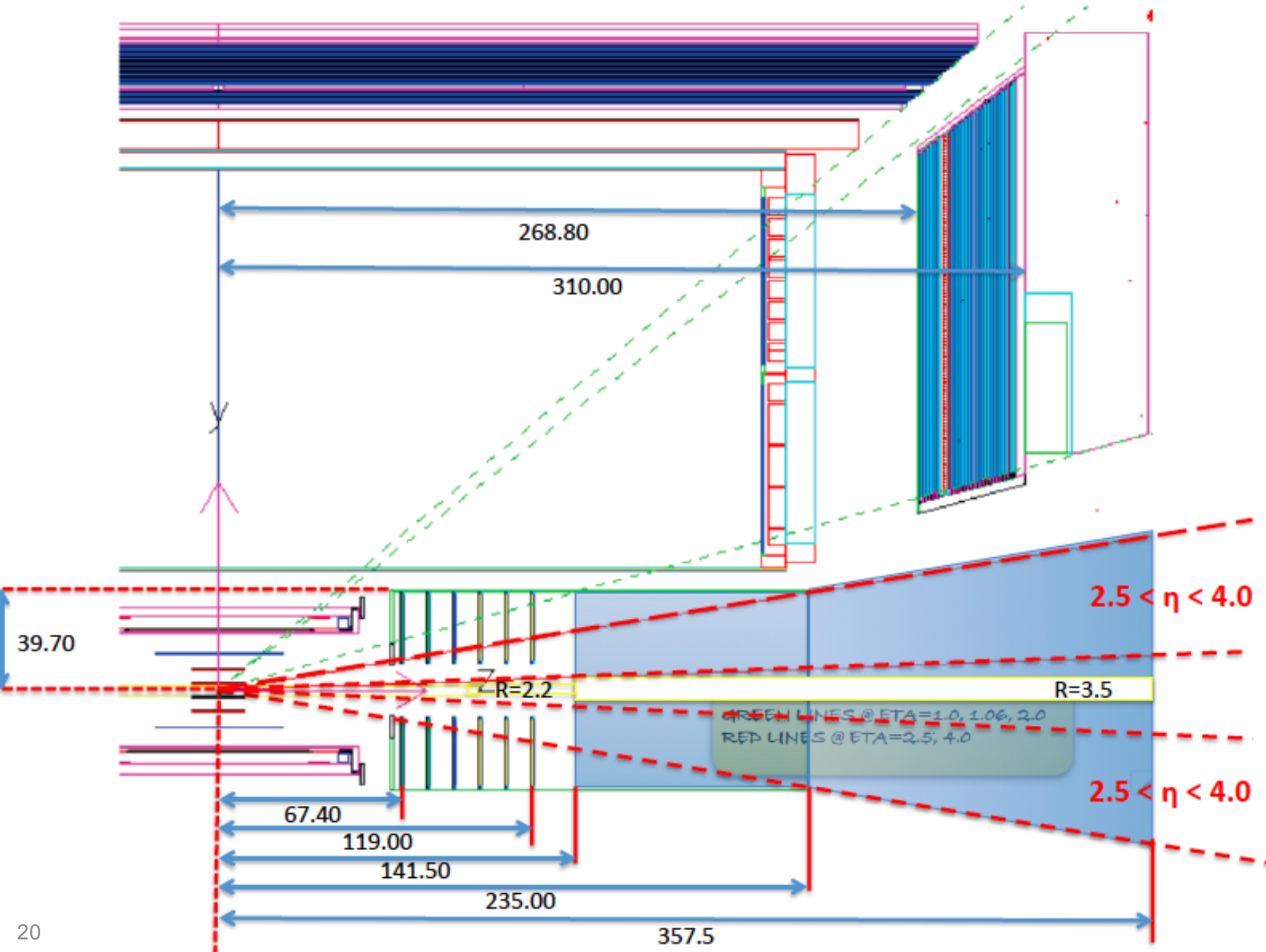
WBS Number	WBS Description FTS (3-disk)	Base Cost	Contingency
y.1.1	Electronics	\$700,000	\$210,000 (30%)
y.1.2	Mechanics	\$740,000	\$333,000 (45%)
y.1.3	Assembly and Testing	\$400,000	\$140,000 (35%)
y.1.4	Integration	\$450,000	\$225,000 (50%)
Base Cost		\$2,290,000	
Contingency		\$908,000	
Total Cost		\$3,198,000	→ \$2,898,000 *

* Cost if re-using IST DAQ and cooling systems

Summary

- A Silicon-based detector can satisfy the needed forward tracking requirements for pp/pA and AA physics programs
- A cost-effective path using APV25 for readout
 - Reuse the existing IST DAQ and cooling
 - Mechanical engineering needed for supporting structure
 - R&D needed for sensor design validation and optimization
- Other option under exploration
 - CBM STS (space, radiation, schedule)

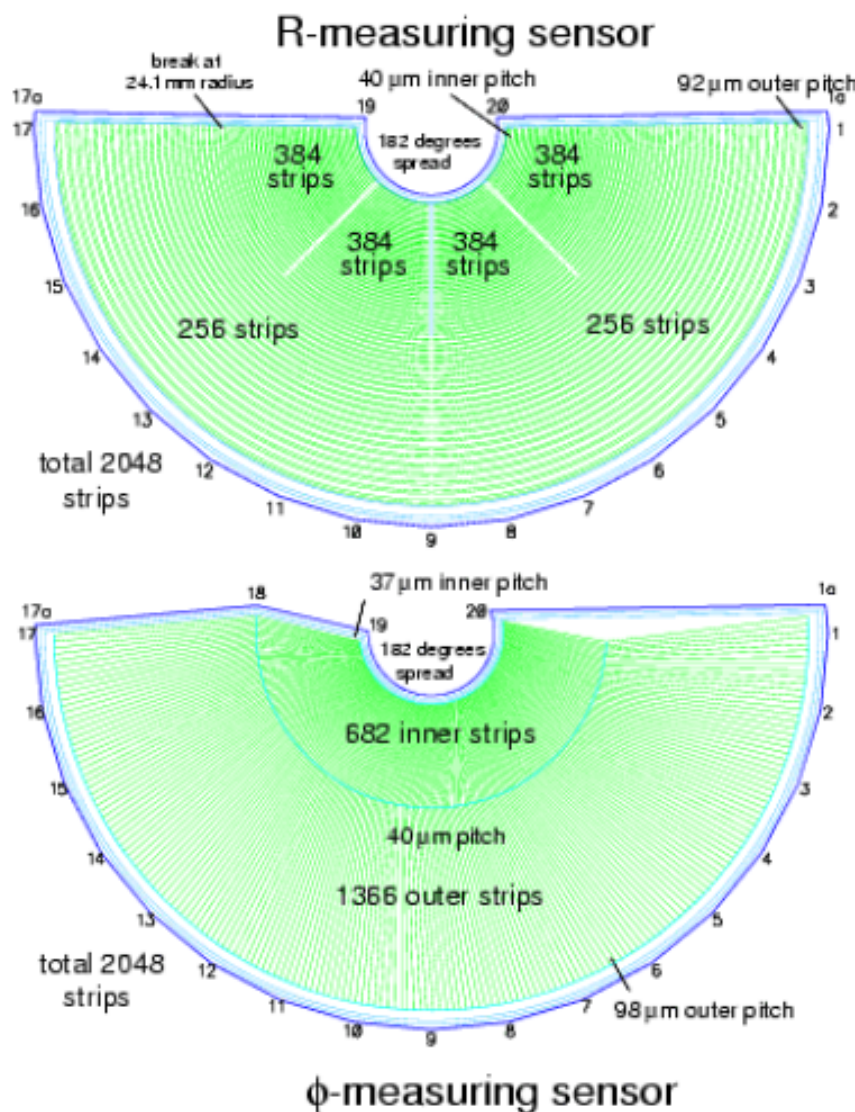
Backup



Requirements (2)

LHCb VELO Detector

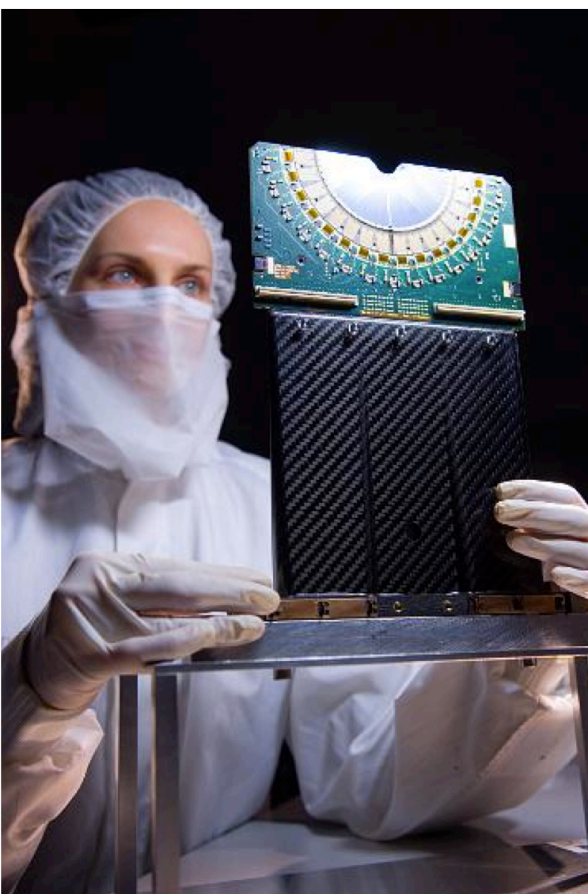
- **Trigger** (see talk by Niels Tuning)
 - **FAST** 2D (rz) and 3D ($rz\phi$) standalone tracking for **L1 Trigger**:
Choose $R\phi$ geometry!
 - Rejection of multiple interactions
- **Baseline Sensor Design**
 - Sensors: $7\text{mm} < R < 44\text{mm}$
(Active area 8mm to 43mm)
 - 182° angular coverage
 - R sensors
 - Pitch $40\mu\text{m}$ to $92\mu\text{m}$
 - 45° inner, 90° outer sections
 - ϕ sensors
 - Pitch $37\mu\text{m}$ to $40\mu\text{m}$ and $40\mu\text{m}$ to $98\mu\text{m}$
 - Double stereo angle



Requirements (2)

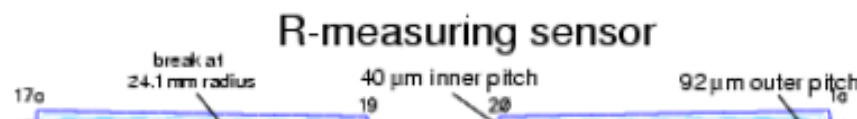
- **Trigger** (see talk by Niels Tuning)
 - **FAST 2D (rz) and 3D ($rz\phi$)**

LHCb VELO Detector



98 μ m

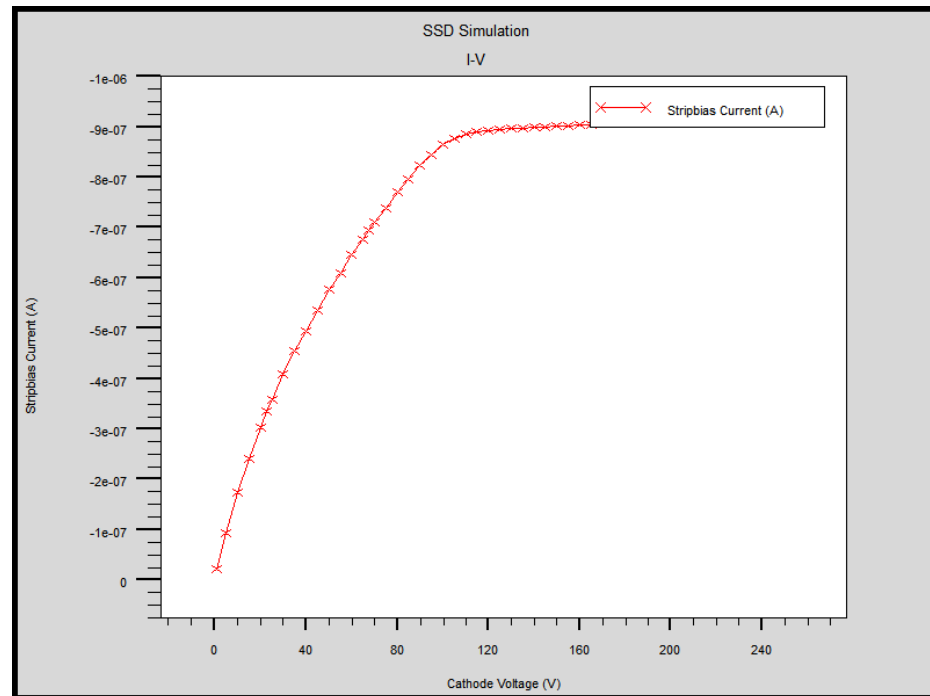
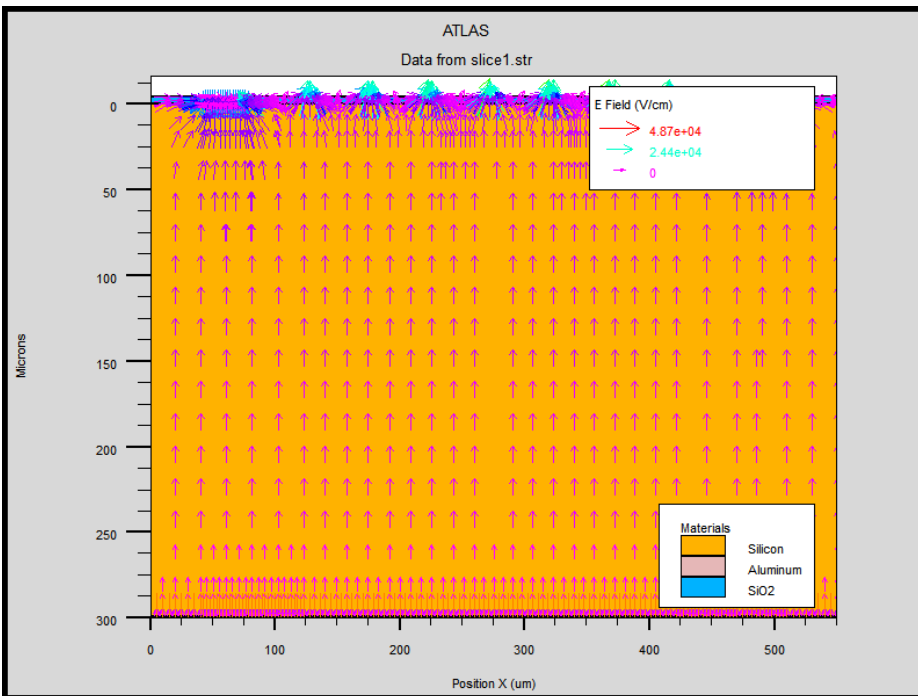
- Double stereo angle



R-measuring sensor

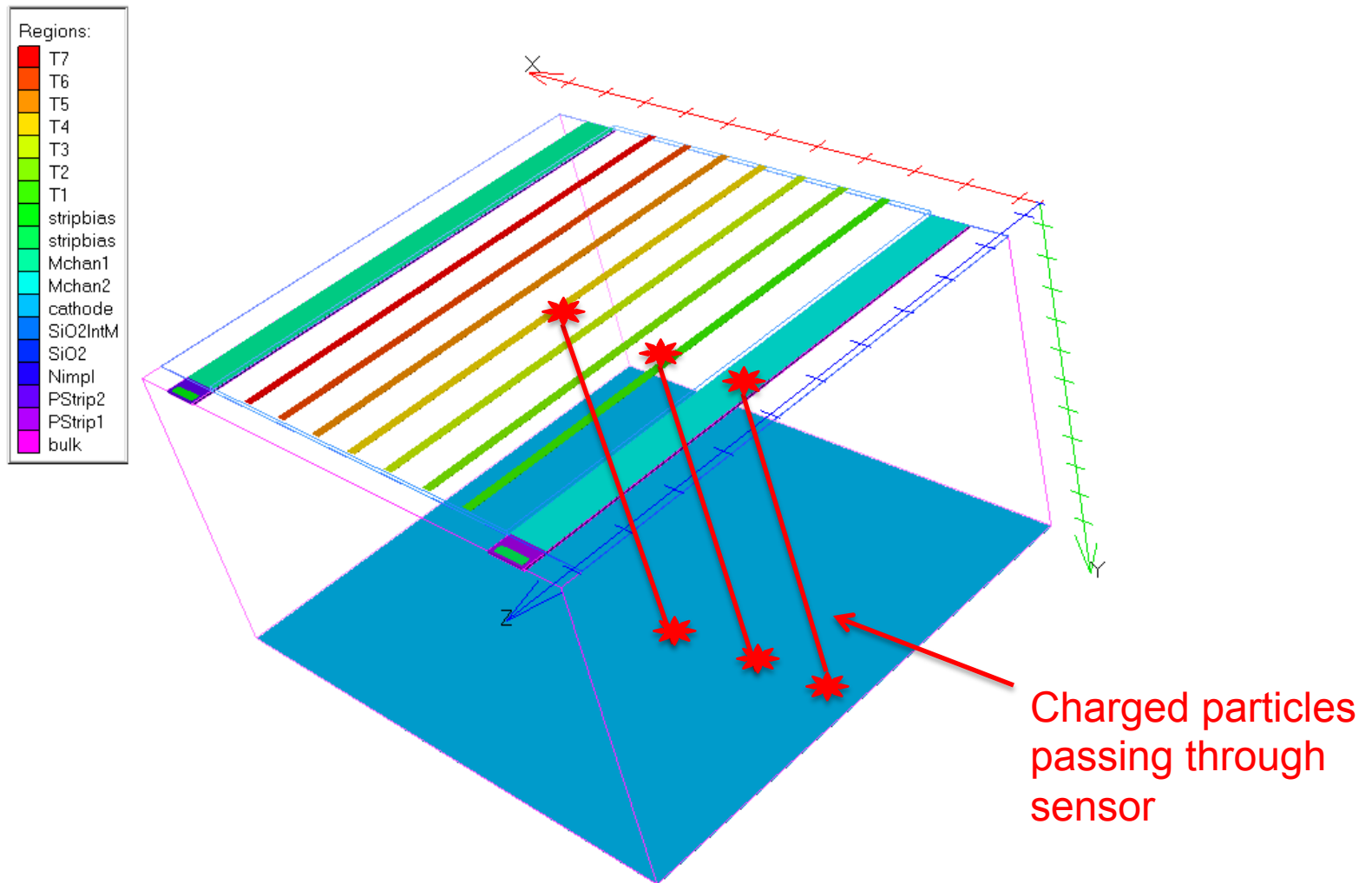
ϕ -measuring sensor

Sensor Simulation

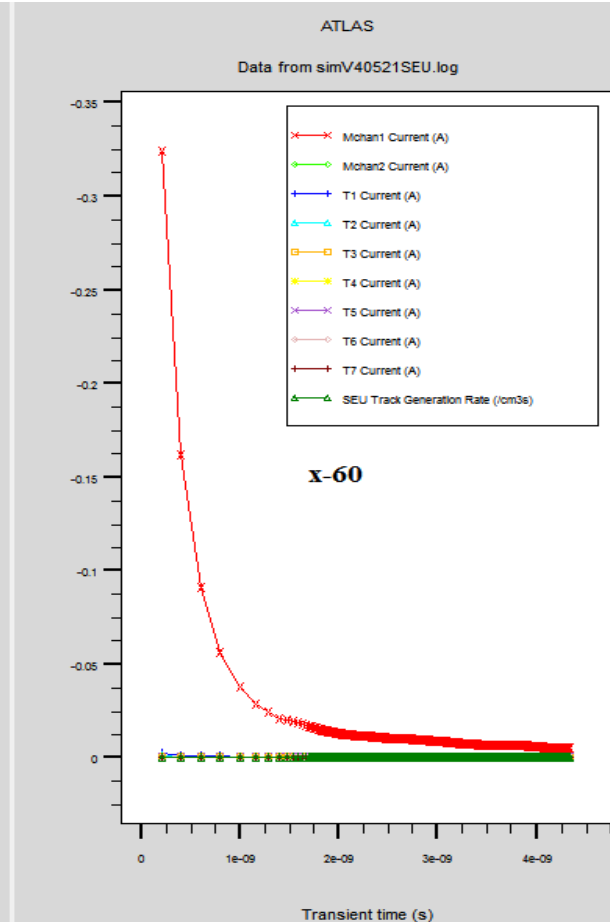
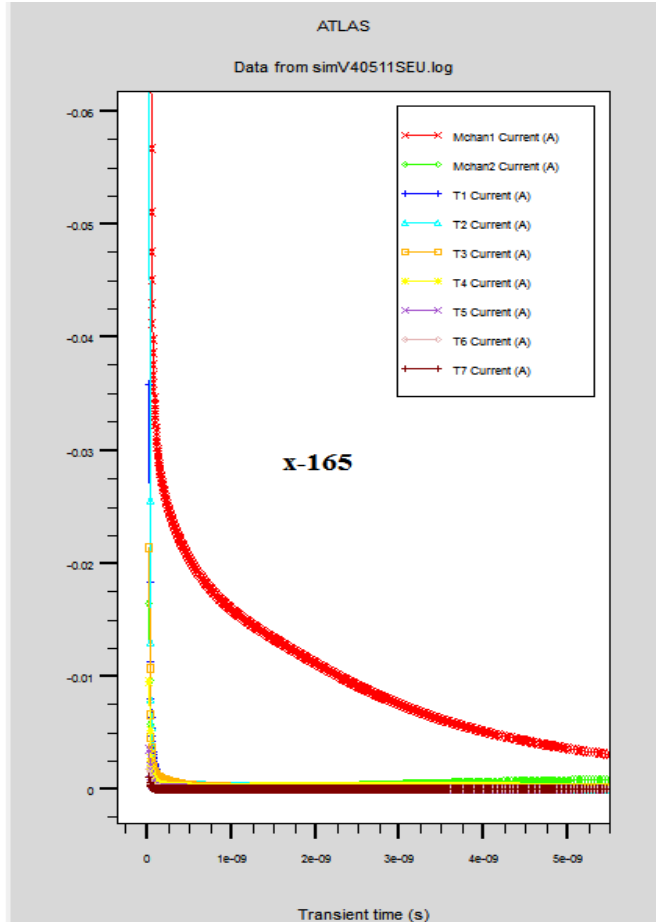
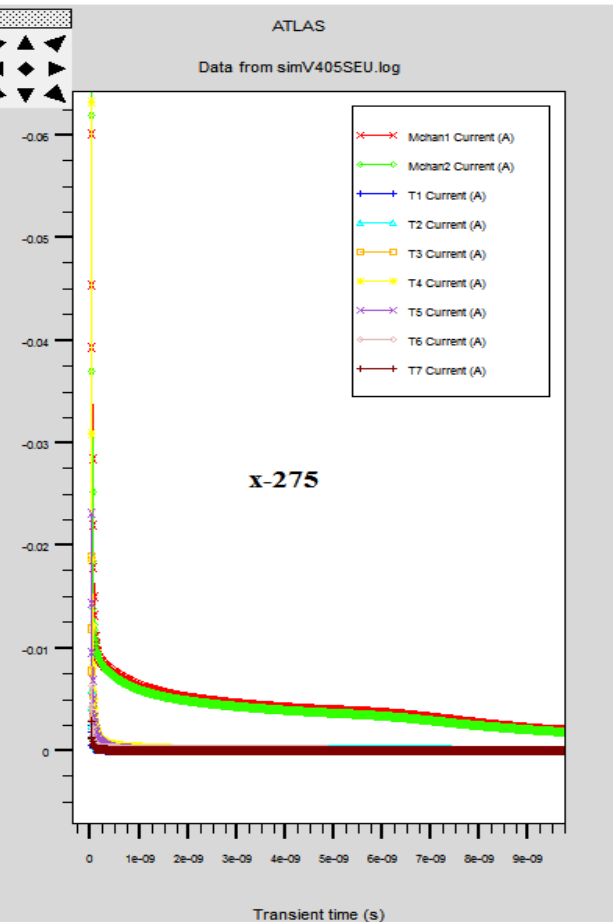


Good DC behavior, full depletion voltage ~ 100 V

Sensor Simulation



Sensor Simulation



Good signal behavior with small amount of cross-talk

Silicon Sensor R&D

Schedule

- Finalize sensor wafer layout and place order – Winter 2017
- Sensor QA test – Spring 2018
- Prototype assembly ~ Summer 2018
- Prototype full performance test ~ Fall 2018

Deliverable

- Proof-of-principle and optimized sensor design
- Full detector system design by the end of year 2018

D0 SMT Forward Disk Assembled at Fermilab

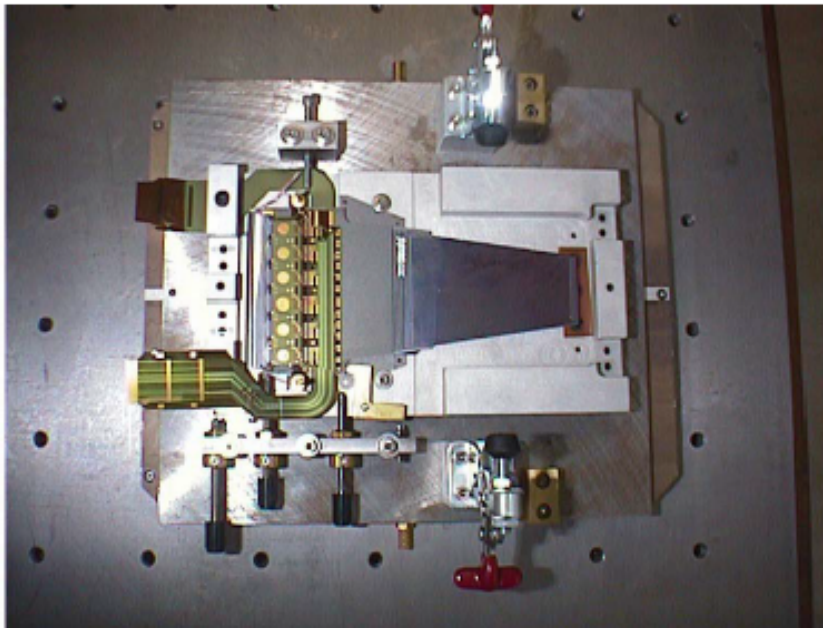
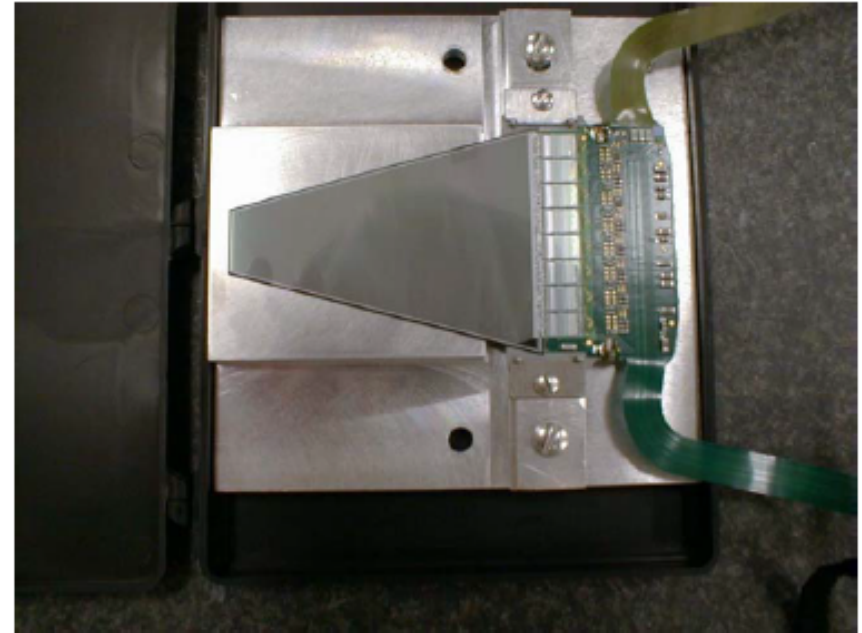


Disk Detectors

F-Wedge Detectors (144)

- 8+6 chip readout
- $2.6 \text{ cm} < r < 10 \text{ cm}$
- Double sided wedges with $\pm 15^\circ$
- $50 \text{ }\mu\text{m}$ (p-side), $62.5 \text{ }\mu\text{m}$ (n-side)
- Variable strip length

D0 SMT



H-Wedge Detectors (384)

- 6+6 chip readout
- $9.6 \text{ cm} < r < 23.6 \text{ cm}$
- Single sided glued back-to-back with $\pm 7.5^\circ$
- $40 \text{ }\mu\text{m}$ (p-side) strip pitch
- $80 \text{ }\mu\text{m}$ readout pitch
- Variable strip length

DO SMT

